EXPERT REPORT OF VICTOR J. BIERMAN, JR.

State of Oklahoma, et al., Plaintiffs
v.
Tyson Foods, Inc., et al., Defendants

Case No. 05-CV-0329-GKF-SAJ

United States District Court for the Northern District of Oklahoma

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OPINIONS AND SUPPORTING STATEMENTS ON EXPERT REPORT BY DR. BERNARD ENGEL

The U.S. Environmental Protection Agency (2008) has issued official guidance on the development, evaluation and application of environmental models. Model evaluation provides information to determine when a model, despite its uncertainties, can be appropriately used to inform an environmental decision. It addresses the appropriateness of a model for a given application, the soundness of the underlying science, the quality and quantity of available data, and the degree to which model results correspond to observations.

Model evaluation includes model corroboration, and sensitivity and uncertainty analyses. This EPA guidance defines model corroboration as quantitative and qualitative methods for evaluating the degree to which a model corresponds to reality. In practical terms, it is the process of "confronting models with data." In some disciplines, this process has been referred to as validation. EPA prefers the term "corroboration" because it implies a claim of usefulness and not truth. Calibration is part of the corroboration process and involves adjusting model parameters until model predictions give the best fit to observed data. Sensitivity and uncertainty analyses investigate how model outputs are affected by changes in selected model inputs.

My expert report begins by addressing the soundness of the underlying science in the models developed by Dr. Engel and the appropriateness of these models for the IRW and the opinions he puts forth. Next it addresses the quality and quantity of the available data, and how these data were used by Dr. Engel to apply his models. Finally it addresses the degree to which the results of Dr. Engel's models correspond to reality. Throughout my report I set forth my opinions on Dr. Engel's methods, results and claims.

1. The entire construct put forth by Dr. Engel is fundamentally flawed. His modeling framework is conceptually flawed and not appropriate for the IRW.

<u>Supporting Statement 1a:</u> The phosphorus mass balance in Dr. Engel's expert report is an inappropriate construct and is not relevant to the relationship between phosphorus sources and water quality.

The phosphorus mass balance in Appendix B of Dr. Engel's expert report is an inappropriate construct that is irrelevant to water quality impacts in IRW streams and rivers, and in Lake Tenkiller. Conceptually, Dr. Engel encased the entire IRW, including all of the air, land and water compartments, in a "bubble" and considered only the phosphorus movements into and out of this "bubble." These phosphorus movements are irrelevant to water quality impacts in the IRW. The only phosphorus movements that are relevant are those that occur inside this "bubble" from land to water or from atmosphere to water.

The mass balance conducted by Dr. Engel completely ignores movement (or delivery) of phosphorus loads from any land-based sources within the IRW to streams and rivers or to Lake

Tenkiller. His analysis does not tell us how much phosphorus reaches the water or how much reaches the lake, and it does not account for WWTP discharges or septic system releases.

On Page 32 of his expert report, Dr. Engel states that poultry production within the IRW is currently responsible for more than 76 percent of the net annual phosphorus additions to the IRW. This claim is based on Dr. Engel's phosphorus mass balance and is a completely misleading representation of the relative contribution of poultry litter phosphorus to water quality impacts in the IRW.

Dr. Engel's mass balance does not consider a "starting point" for phosphorus in the IRW because it includes only sources and sinks of phosphorus, not reservoirs of phosphorus already present. Table 11 in Appendix B of Dr. Engel's expert report indicates that phosphorus additions to the IRW from poultry were 4,642 tons in 2002. From materials produced by Dr. Engel, the total phosphorus mass in the IRW soil in his GLEAMS model is 6,370,998 tons. This reservoir represents the sum of phosphorus mass for actual conditions (1997-2006) in all soil horizons (layers) in his GLEAMS model. The bottom depths of these soil horizons range from 15.24 to 83.93 inches, depending on location.

Consequently, the annual phosphorus addition to the IRW from poultry litter represents less than 0.07 percent of the total phosphorus mass already present in the soil of the IRW, as represented in Dr. Engel's GLEAMS model. This phosphorus mass reservoir of 6,370,998 tons is not accounted for in the phosphorus mass balance that Dr. Engel conducted.

<u>Supporting Statement 1b:</u> The GLEAMS model used by Dr. Engel is an inappropriate tool for predicting watershed-scale nonpoint source phosphorus loads to streams and rivers in the IRW.

GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) was developed to simulate edge-of-field and bottom-of-root zone loadings of water, sediment, pesticides and plant nutrients from agricultural fields. GLEAMS is a field-scale model and operates at daily time scales. Dr. Engel inappropriately used GLEAMS to predict watershed-scale nonpoint source phosphorus loads from the land to streams and rivers for the entire IRW. In addition, he used GLEAMS for the IRW despite its limitations and uncertainties for predicting phosphorus loads that he identified in his own previous work, as discussed below.

In a U.S. Environmental Protection Agency (EPA) report entitled, "TMDL Model Evaluation and Research Needs," Shoemaker et al. (2005) describe GLEAMS as a continuous simulation, field-scale model that assumes that a field has homogenous land use, soils and precipitation. They characterize GLEAMS as an edge-of-field model that has a low level of support for watersheds and no support for receiving waters.

Shoemaker et al. (2005) specifically state three limitations for use of the GLEAMS model:

- Limited to an agricultural field of very small size
- Not suited for bigger watersheds
- Not suited for urban land uses.

<u>Supporting Statement 2e:</u> Most of the inputs for Dr. Engel's GLEAMS model are default or generic values and are not based on conditions in the IRW.

Model outputs cannot be accurate and reliable unless the model inputs represent real-world conditions in the system being modeled. In other words, garbage in equals garbage out. Most of the inputs used by Dr. Engel for his GLEAMS model were default or generic values that were not based on data for the IRW, nor were they shown to reasonably represent conditions in the IRW. This calls into question the accuracy and reliability of his model predictions for nonpoint source phosphorus loads to streams and rivers in the IRW.

There are several ways in which a GLEAMS model user can provide plant nutrient input parameters for a particular application. Two examples of such parameters would be CLAB (labile phosphorus concentration in the soil horizon) and RATE (rate of application of animal waste). First, the GLEAMS model itself can provide its own plant nutrient input parameters. For example, if a user provides their own input value for CLAB, GLEAMS can distribute this value into the appropriate computational layers. If soil nutrient data are available for local soils the user should input those values, but if such data are not available, generalized estimates can be generated by GLEAMS itself.

Second, GLEAMS contains a default database for plant nutrient input parameters that represents data compiled from a number of sources and locations. This database is not specific to the IRW. The GLEAMS user can decide whether to use actual data for local soils or the default data base contained in GLEAMS.

Third, as a starting point for a site-specific application, a GLEAMS user could simply decide to use plant nutrient input parameters from the several example tables in the appendices to the GLEAMS Manual (Knisel and Davis 2000). These values could be from the default database in GLEAMS, generalized estimates generated by GLEAMS, or from other sources. Again, these values are not specific to the IRW.

I will use the term "default" to refer to the default values in the GLEAMS database and the generalized estimates generated by the GLEAMS model itself. I will use the term "generic" to refer to values taken directly from one of the example tables in the appendices to the GLEAMS Manual.

The U.S. EPA (2008) guidance on environmental models is clear on the importance of using real-world data for model inputs. On Page 16 it states, "*The most appropriate data ... should always be selected for use in modeling analyses. Whenever possible, all parameters should be directly measured in the system of interest.*" On Page 19 it states, "*Even though a modeling framework (or system of equations) might be technically sound, a particular site-specific application of the modeling framework may still be highly uncertain if the data used to construct the application are limited in quantity or quality. For such an application, the model would not have the necessary scientific credibility or utility to support an environmental decision.*"

On Page 137 of the GLEAMS Manual (Knisel and Davis 2000) in the section on "Nutrient Parameters Description," it states that, "*The plant nutrient component of GLEAMS and the associated parameter values allow the user to make a generalized application with model-initialized parameters or very site-specific detailed user-defined initialization.*" The claims and opinions put forth by Dr. Engel in his expert report on phosphorus loads to Lake Tenkiller, and on which phosphorus loads come from which land uses, are not generalized but are intended to be specific to the IRW. These claims cannot be supported with a generalized application of GLEAMS, but must be supported with site-specific data that reflect real-world conditions in the IRW.

Most of values used by Dr. Engel for his GLEAMS nutrient parameter input files were default or generic values, not values based on any actual data from the IRW. In his expert report, Dr. Engel did not describe any investigations he conducted to determine whether these default or generic values were appropriate for the IRW. This calls into question the accuracy and reliability of his model results.

Summaries of the actual plant nutrient parameter input files that Dr. Engel used for pasture, crop, forest and urban land uses in his GLEAMS model are contained in Appendix B of my expert report. Also included in Appendix B are tables containing line-by-line descriptions of each plant nutrient parameter input file for each of these land uses. Below are concise summaries of my key points for the nutrient parameter inputs used by Dr. Engel in his GLEAMS model.

Pasture is the most important land use category in Dr. Engel's GLEAMS model because he represents almost half of the 1,000,000 acres in the IRW as pasture land and he assumes that poultry litter is applied to every acre of this pasture land. His GLEAMS model inputs for pasture land are based directly on example Table A-19 from the GLEAMS Manual (Table 1). He used 10 default values from GLEAMS and 10 generic values taken directly from Table A-19. Note that blanks in GLEAMS model input files signify that the internal GLEAMS default value is used instead of a value externally specified by the user.

For pasture land, Dr. Engel provided his own values for only seven of the 27 required GLEAMS nutrient parameter inputs (Page D-41 of his expert report):

- AOM: organic matter content in animal waste
- APHOS: total phosphorus content in animal waste
- APORGP: organic phosphorus content in animal waste
- CLAB: labile phosphorus concentration in the soil horizon
- DF: date of fertilizer application
- RATE: application rate for animal waste
- RESDW: crop residue on the ground surface when simulation begins

Apart from CLAB, as discussed above, four of these seven nutrient parameter inputs are described on Page D-18 of Dr. Engel's expert report. These include RATE for total applied litter (223,000 tons/year on a dry weight basis), APHOS (2.08%), APORGP (0.98 organic P/total P) and DF (April 1).

The most important of these GLEAMS nutrient inputs are RATE, APHOS and total applied litter phosphorus (4,642 P tons/year). As described on Pages 19 and 20 in Appendix B of Dr. Engel's expert report and summarized in two spreadsheets (Smith00003221_New_Calculations.xls and Engel00000186_Poultry_Comp_forBernie.xls) produced by the Plaintiffs, the only data from the IRW Dr. Engel used to develop the GLEAMS input values for these parameters were the numbers of birds in each IRW county. All of the other data required to develop input values for these parameters (average manure generation rates in lb/finished bird, average moisture contents, average percent total phosphorus on a dry weight basis, and average bird weights at market) were taken from Nutrient Management Plans (NMPs) for a different watershed than the IRW. Ms. Megan Smith, who conducted the phosphorus mass balance study in Appendix B of Dr. Engel's expert report, under Dr. Engel's direction, admitted in her September 10, 2008, deposition that she does not know if the values reported in these NMPs are calculated numbers or production numbers based on actual data, and that she never investigated this.

Not only were most of the data used to develop these important parameters taken from a watershed other than the IRW, but Dr. Engel ignored phosphorus measurements for litter samples (APHOS) collected by the Plaintiffs from 20 poultry houses in the IRW, as well as samples collected from poultry litter fallen from trucks (Olsen Expert Report, Page 2-3). Dr. Engel derived his value for APHOS by simply dividing total applied litter phosphorus (4,642 P tons/year, Appendix B, Engel expert report) by his value for total applied litter (223,000 tons/year on a dry weight basis) for the IRW.

The rates of poultry litter application (RATE) assumed by Dr. Engel in his GLEAMS model do not reflect actual practices in the IRW. Dr. Engel divided all of the pasture land in the IRW into four zones and assumed that poultry litter in his GLEAMS model was applied uniformly to each acre within each of these four zones. In his deposition he stated that the rates of application he assumed in his model were not the rates per acre actually applied in the IRW. This is important because half of the 1,000,000 acres in the IRW in Dr. Engel's GLEAMS model is represented as pasture land and he applies poultry litter to all pasture land in his model.

Dr. Engel also assumed that all of the poultry litter in his GLEAMS model is applied on a single day each year (NF = 1) for all pasture land in the entire IRW and that this date is April 1 (DF = April 1). This does not reflect actual practices in the IRW, nor is it consistent with Dr. Engel's own expert report. As shown in Figure 4.1 of Dr. Engel's report, poultry litter is applied in the IRW during each month from January to December of each year.

This means that in Dr. Engel's GLEAMS model the total amount of poultry litter applied for the entire year is applied on a single day in a single "heap" regardless of whether it is raining or dry. This does not reflect actual practices in the IRW.

Dr. Engel determined APORGP by using APHOS and assuming that the ratio of organic and total phosphorus taken from the GLEAMS Manual (Knisel and Davis 2000) was appropriate for the IRW. He did not document how he determined AOM or RESDW in his GLEAMS model.

For crop and forest land use areas, again most of nutrient parameter inputs Dr. Engel used for his GLEAMS model are default or generic values, with the exception of CLAB as described above. His GLEAMS inputs for crop land are based on example Table A-20 from the GLEAMS Manual (Table 2). He used 28 default values and 37 generic values taken directly from Table A-20. His GLEAMS inputs for forest land are based on example Table A-21 from the GLEAMS Manual (Table 3). He used 20 default values and three generic values taken directly from Table A-21.

There are no examples for plant nutrient input files in the GLEAMS Manual for urban land because GLEAMS is an agricultural model. Dr. Engel set his GLEAMS inputs for urban land use with alfalfa-hay as the specified crop type. As described above, this is a misrepresentation because urban land is very different than agricultural land for growing hay. Dr. Engel used 18 default values and four generic values taken directly from Table A-21.

Overall, Dr. Engel used default or generic values for 130 of the 140 (93 percent) plant nutrient input parameters that he needed to run his GLEAMS model for the IRW. These default and generic values are not based on site-specific data for the IRW, nor is there any documentation in Dr. Engel's report of investigations he conducted to determine whether these values were appropriate for the IRW.

In summary, the phosphorus component of Dr. Engel's GLEAMS model is almost entirely a generalized application and is not specific to the IRW. Dr. Engel has not demonstrated that the nutrient inputs to his GLEAMS model represent real-world conditions in the IRW. If his model inputs do not represent real-world conditions, then neither can his model outputs. Consequently, Dr. Engel cannot claim that predictions from his model for phosphorus loads to streams and rivers in the IRW, or his predictions for which phosphorus sources come from which land uses, are accurate and reliable.

<u>Supporting Statement 2f:</u> In contravention to generally accepted practices in the scientific community, Dr. Engel did not compare the predictions for hydrology from his GLEAMS model to any observed data in the State of Arkansas or to most of the observed data in the State of Oklahoma.

To demonstrate that a model corresponds with reality it must be "confronted with data." A thorough model evaluation includes comparison of model predictions with the available site-specific data. If substantial portions of the available site-specific data are "left out" during the model evaluation process, a model cannot be considered accurate and reliable. While it would be appropriate to ignore observed data that fail to meet QA/QC criteria or that are not representative of the true system being modeled, Dr. Engel ignored the vast majority of the data available to him when he calibrated and purported to validate the hydrology component of his GLEAMS model.

This point is emphasized on Page 3 of SERA-17 (2005) where it is stated that, *"In our opinion, watershed-scale predictions of loadings to lakes are not reliable unless extensive, site-specific calibration is used."*

There are 15 USGS stations with measurements for daily average flow in the IRW (Figure 8). Dr. Engel compared the hydrology outputs from his GLEAMS model to observed data for monthly average flow at only three of these stations, Illinois River near Tahlequah, Baron Fork at Eldon, and Caney Creek near Barber. These are the last three stations before Lake Tenkiller and are the outlets for each of these three subwatersheds to the lake.

Dr. Engel ignored all of the observed data that were available at the seven USGS stations in Arkansas. These stations represent 22,273 measurements of daily average flow during 1997-2006. Dr. Engel also ignored observed data that were available at five additional USGS stations in Oklahoma besides the three outlet stations. These stations represent 17,074 measurements of daily average flow during 1997-2006.

Overall, there is a total of 50,030 measurements of daily average flow at the 15 USGS stations in the IRW during 1997-2006, including the three outlet stations on the Illinois River near Tahlequah, Baron Fork at Eldon and Caney Creek near Barber. Dr. Engel ignored 79 percent of these measurements in his calibration and purported validation of the hydrology outputs from his GLEAMS model.

It is important to check a watershed model "along the way," not just at the downstream outlets. Failure to do so undermines the accuracy and reliability of the model for attributing the relative contributions of sources in the watershed. It is not just about how much water gets to the outlets, but also about where it came from and how it got there. If a model is to be used to make claims about phosphorus loads originating from local sources in the watershed, then it must be confronted with data that actually represent these local sources.

U.S. EPA (2008) recommends conducting sensitivity analyses to characterize the most and least important sources of uncertainty in environmental models. Sensitivity analysis investigates how model outputs are affected by changes in selected model inputs. On Page D-41 of his expert report Dr. Engel lists eight soil parameters that he calibrated and purported to validate for the hydrology component of his GLEAMS model. Dr. Engel stated in his deposition that he did not perform any sensitivity analyses with his models for the IRW. Consequently, the impacts of uncertainties in his GLEAMS hydrology parameters on the model results were not established and are unknown.

Supporting Statement 2g: In contravention to generally accepted practices in the scientific community, Dr. Engel did not compare the predictions for phosphorus loads to edge-of-field from his GLEAMS model to any observed data in the States of Arkansas or Oklahoma.

Dr. Engel's GLEAMS model predicts phosphorus loads at edges of streams and rivers in the IRW, and his routing model predicts phosphorus loads delivered to Lake Tenkiller at the last three USGS stations upstream of the lake. These two models are linked in series with the output of the GLEAMS model providing the input for the routing model. Dr. Engel uses these two linked models to predict not only the phosphorus loads to Lake Tenkiller, but the relative contributions of poultry litter to these phosphorus loads.

The U.S. EPA (2008) guidance on environmental models states on Page 12, that *"When employing linked models, the project team should evaluate each component model as well as the full system of integrated models at each stage of the model development and evaluation process."* Dr. Engel presented no results in his expert report for the evaluation of his GLEAMS model, but presented results only for his routing model by comparing it with observed phosphorus loads to Lake Tenkiller.

The phosphorus loads to Lake Tenkiller are a "soup" that represent the sum of all phosphorus sources in the entire IRW and contain no information on the relative contributions of any individual source. For Dr. Engel's models to support claims on the relative contributions of poultry litter, they must be "confronted with data" at the source of these poultry litter contributions, not at the last three stations before the lake where these contributions have become part of the "soup." This means that Dr. Engel's GLEAMS model must be compared with observed data at edge-of-field.

This point is emphasized on Page 3 of SERA-17 (2005) where it is stated that, *"In our opinion, watershed-scale predictions of loadings to lakes are not reliable unless extensive, site-specific*

Finally, the concept of model "validation" put forth by Dr. Engel is at odds with the position by Dr. Scott Wells, another expert for the Plaintiffs who used the results from Dr. Engel's models for his own model of Lake Tenkiller. Dr. Wells presented a paper entitled, "Surface Water Hydrodynamics and Water Quality Models: Use and Misuse" at the 23rd Annual Water Law Conference, San Diego, CA, February 24-25, 2005. On Page 9 of that paper Dr. Wells states, *"If a model is applied to an independent data set and the model matches data well with the original parameter set, then one can say that the model was calibrated well to the 2 time periods under consideration. When the term validation is used, it makes others think that the model is "valid" and does not have serious weaknesses. This though can be an inappropriate label. Hence, discarding the term altogether would eliminate this misconception."*

Again, consistent with U.S. EPA (2008) guidance, and with the position by Dr. Wells, Dr. Engel's purported "validation" is an inappropriate characterization and no claims of validity or lack of serious weaknesses can be implied.

Not only were the models in Dr. Engel's expert report not validated, but the calibration approach used by Dr. Engel was circular and fundamentally flawed. Consequently, the results from his models do not have scientific credibility nor are they useful for supporting environmental decisions.

<u>Supporting Statement 2j:</u> Dr. Engel did not follow his own published guidance on procedures for standard application of hydrologic/water quality models.

Dr. Engel was the senior author on a paper entitled, "A Hydrologic/Water Quality Model Application Protocol," that was published in the Journal of the American Water Resources Association, October 2007, Volume 43, No. 5, Pages 1223-1236. This paper was co-authored by Dan Storm, Mike White, Jeff Arnold and Mazdak Arabi.

On Page 1224 of his paper, Dr. Engel stated that, *"By definition, the scientific method is impartial and the results from the application of the scientific method must be reproducible. Therefore, the modeling protocol and associated documentation must provide enough detail to allow the modeling project to be repeated."*

On Page 1231 of his paper, Dr. Engel stated that, *"For projects supporting regulatory decision-making, the USEPA (2002) suggests the level of detail on model calibration in the Quality Assurance Project Plan should be sufficient to allow another modeler to duplicate the calibration method, if the modeler is given access to the model and to the data being used in the calibration process."*

In an E-mail on August 13, 2008, from David Page to Robert George, the following information was provided in response to a request by the Defendants for a step-by-step procedure for generating GLEAMS model outputs for daily phosphorus loads: *"Calibrated yearly GLEAMS files were manually modified to better match P load timing by modifying labile phosphorus concentrations in the soil horizon."*

A letter on December 8, 2008, from Ms. Claire Xidis to Mr. Robert George, stated that " ... *Dr. Engel has informed us that the parameters used for the routing equations are included in the errata. These were obtained by adjusting the parameters to match the observed data. The*

3. The modeling results put forth by Dr. Engel in his expert report are not accurate or reliable to a reasonable degree of scientific certainty.

Supporting Statement 3a: The routing model developed by Dr. Engel can be calibrated using a wide range of different watershed loadings, including random values; consequently, his calibration does nothing to corroborate his GLEAMS model outputs or his WWTP loads.

The models developed by Dr. Engel are insensitive to changes in the timing of his phosphorus loads to streams and rivers in the IRW and to wide ranges in the magnitudes of his phosphorus loads from nonpoint source runoff and WWTPs. It can even be shown that predictions from Dr. Engel's phosphorus routing model can still be calibrated to his observed phosphorus loads to Lake Tenkiller for random inputs. In practical terms, Dr. Engel's models cannot tell the difference between actual phosphorus loads to streams and rivers in the IRW and phosphorus loads that are simply made up.

I conducted a series of analyses with the phosphorus routing model described on Page D-21 of Dr. Engel's expert report. I conducted these analyses using Dr. Engel's routing model spreadsheet ("p_model_10_15.xls") and values from within his allowable ranges for each of the four coefficients (a, b, c and initial P accumulation) in this model, as described in his expert report and in his deposition.

Figure 19 shows that if the chronologies for Dr. Engel's predicted phosphorus loads to streams and rivers in the IRW for 1998-2006 are reversed, his phosphorus routing model can still be calibrated to his observed phosphorus loads to Lake Tenkiller. Specifically, Dr. Engel's predicted daily nonpoint source loads from GLEAMS plus his WWTP loads were reversed from last day to first day for each of the three subwatersheds in the IRW. Upon comparison of results in Figure 19 with those in Dr. Engel's expert report (reproduced in the top panels of Figures 15-17) it can be seen that the results for the reversed chronologies are practically the same for the Illinois River near Tahlequah (R^2 decreases from 0.974 to 0.963) and are actually improved for both Baron Fork (R^2 increases from 0.781 to 0.914) and Caney Creek (R^2 increases from 0.625 to 0.7214).

This demonstrates that Dr. Engel's models are not sensitive to the timing of his predicted daily phosphorus loads over his 9-year calibration and purported validation period from 1998 to 2006. In fact, his models produce somewhat better results when his predicted daily phosphorus loads (plus WWTP loads) are run backwards in time. Because predicted daily phosphorus loads from his GLEAMS model are driven by rainfall events, and he treated WWTP loads as daily background loads, this means that Dr. Engel's linked GLEAMS and routing models cannot tell the difference between rainy days and dry days in the IRW.

It can also be shown that wide ranges in the magnitudes of Dr. Engel's WWTP loads, and his predicted phosphorus loads from GLEAMS, can still be calibrated to his observed phosphorus loads to Lake Tenkiller by his phosphorus routing model. Figure 20 shows the ranges in each of these phosphorus load components to streams and rivers in the IRW that can still be calibrated to Dr. Engel's observed P loads to Lake Tenkiller each year from 1998 to 2006. The top panel shows results for WWTP loads to streams and rivers, and the bottom panel shows results for predicted phosphorus loads from GLEAMS to streams and rivers. Note that the phosphorus loads in this figure are shown on logarithmic scales. The vertical scales in each panel are extremely large and range from 10,000 to 1,000,000,000 lbs P/year.

For each of the three subwatersheds (Illinois, Baron Fork and Caney Creek), Dr. Engel's routing model was re-calibrated to fit these increased WWTP and GLEAMS nonpoint source loads to his observed phosphorus loads to Lake Tenkiller with R^2 values equal to or greater than those in his expert report.

In practical terms, if there were an additional 96,727,276 people in the IRW, an almost 345-fold increase, then Dr. Engel's routing model can still be calibrated to his observed phosphorus loads to Lake Tenkiller with the additional WWTP loads from this population (plus the nonpoint source phosphorus loads from GLEAMS). This WWTP load estimate is based on a human population of 280,383 in 2000 (Table 2 in Appendix B of Dr. Engel's expert report) and an annual per capita production rate of 1.298 lbs P/year which can be calculated from the information in Tables 2 and 3 of Appendix B. This example is conservative because it assumes that all of the waste generated from the additional population is untreated and that 100 percent of it is delivered directly to streams and rivers in the IRW.

Again in practical terms, if there were an additional 2,356,541,356 birds per year in the IRW, a greater than 15-fold increase, then Dr. Engel's routing model can still be calibrated to his observed phosphorus loads to Lake Tenkiller with the additional nonpoint source phosphorus loads from GLEAMS (plus Dr. Engel's WWTP loads). This estimate of additional birds is based on materials produced by Dr. Engel ("Smith00003221_New_Calculations.xls") stating that there were 151,781,155 birds (broilers, layers, pullets, turkeys) in the IRW in 2002 and that each bird produces an average of 0.0612 lb P/year. Again, this example is conservative because it assumes that all litter from these additional birds is applied to pastures and that 100 percent of the phosphorus in this litter runs off to streams and rivers.

I make no claim that the annual per capita production rate of 1.298 lbs P/year or the average annual production rate per bird of 0.0612 lb P/year are accurate, but only that these are the values that can be derived from materials produced by Dr. Engel.

These results show that the phosphorus routing model developed by Dr. Engel, when presented with a wide universe of possibilities, cannot even come close to "pinning down" the real nonpoint source runoff loads to streams and rivers in the IRW, nor can it tell the difference between Dr. Engel's WWTP loads and WWTP loads that are many times higher.

Furthermore, if Dr. Engel's routing model cannot "pin down" either of these individual phosphorus sources, then neither can it "pin down" their relative contributions. Because his model cannot tell the difference between such a large increase in a particular source, then it cannot be accurate and reliable for allocating phosphorus loads back to individual sources in the IRW.

As a final demonstration that Dr. Engel's phosphorus routing model cannot "pin down" the real phosphorus loads to streams and rivers in the IRW, I determined that it can actually be calibrated to his observed phosphorus loads to Lake Tenkiller for random inputs. Figure 21 shows predicted versus observed phosphorus loads to Lake Tenkiller in the Illinois River near Tahlequah for the calibration and purported validation results in Dr. Engel's expert report (top panel) and daily S&P 500 Stock Index values (bottom panel) for the same period (1998-2006). The R^2 values are 0.974 for both sets of results. In simple terms, Dr. Engel's routing model cannot tell the difference between phosphorus loads to streams and rivers in the IRW and stock index values.

In summary, the models developed by Dr. Engel are conceptually flawed, not scientifically credible and not reliable quantitative tools. His models can accept inputs that do not make any sense and calibrate these inputs to his observed phosphorus loads to Lake Tenkiller. Therefore, the relationships between his model inputs, which are phosphorus loads from the watershed, and his observed phosphorus loads to Lake Tenkiller make no sense.

Dr. Engel's models cannot tell the difference between rainy days and dry days in the IRW, nor can they tell the difference between his own phosphorus loads to streams and rivers, and phosphorus loads that are simply made up. When presented with a wide universe of possibilities, Dr. Engel's routing model cannot even come close to "pinning down" the real phosphorus loads to streams and rivers in the IRW, nor can it "pin down" the relative contributions of individual sources. Dr. Engel's models are not reliable quantitative tools for predicting phosphorus loads to Lake Tenkiller or the relative contributions of any individual sources to these phosphorus loads.

<u>Supporting Statement 3b:</u> The opinion by Dr. Engel that poultry litter land application in the IRW is a substantial contributor to phosphorus loads to Lake Tenkiller is based on model results and methods that are conceptually flawed, incorrect and not reliable.

Opinion 8 on Page 2 of Dr. Engel's expert report states that, "Poultry waste land application in the IRW is a substantial contributor (45% between 1998 and 2006 and 59% between 2003 and 2006) to P loads to Lake Tenkiller, representing the largest P source." The phosphorus allocation to each source is shown in Tables 10.14 and 10.15 on Page 93 of Dr. Engel's expert report.

First, Opinion 8 is based on results from Dr. Engel's models that are not reliable to a reasonable degree of scientific certainty. Second, even if Dr. Engel fixes all of the deficiencies in his models, as described above in my Opinion 2 and Supporting Statements 2a through 2m, and follows SERA-17 guidance, U.S. EPA recommendations on environmental models, and his own protocol for application of hydrologic/water quality models, his entire modeling framework remains conceptually flawed and inappropriate for the IRW. Third, as described below, the methods that Dr. Engel used to develop the phosphorus allocations to sources in his Opinion 8 are themselves conceptually flawed, undocumented, contain numerous errors and inconsistencies, and are not reliable to a reasonable degree of scientific certainty.

Dr. Engel's models predict only total phosphorus loads and contain no information on individual sources of phosphorus. He stated in his deposition that neither his GLEAMS nor his routing model identifies poultry litter as a phosphorus source and that this identification requires interpretation of outputs from these models after they are run. Dr. Engel uses a separate allocation method ("allocation_5_2.xls") to process and interpret the outputs from his GLEAMS and phosphorus routing models, and determine the relative contributions of individual sources to phosphorus loads to Lake Tenkiller. Despite the importance of these results in forming his Opinion 8, Dr. Engel did not include any documentation in his expert report of the methods he

APPENDIX B

ANALYSIS OF GLEAMS MODEL INPUT FILES

Table B-1. Summaries of Dr. Engel's Plant Nutrient Parameter Input Files for Pasture Land Use

Sources of Information:

1) GLEAMS original (initial) parameter input values were extracted from the 1N.PAR files and 2NP.PAR files located in the following directories:*
"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR\ILLINOIS\ORGINPUT
"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR\BARRONFORT\OriginInput
"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR\CANEYCREEK\OriginInput
2) GLEAMS calibrated (final) parameter input values were extracted from the 1N.PAR files located in the ILLINOIS, BARRONFORT, and CANEYCREEK sub-folders:*
"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR"*
3) Knisel, W.G. and Davis, F.M. 2000. GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), Version 3.0, User Manual. Pub. No. SEWRL-WGK/FMD-050199.
4) "Expert Report" refers to "Poultry Waste Generation and Land Application in the Illinois River Watershed and Phosphorus Loads to the Illinois River Watershed Streams and Rivers and Lake Tenkiller, Expert Report of Dr. B. Engel, For State of Oklahoma, In Case No. 05-CU-329-GKF-SAJ, State of Oklahoma v. Tyson Foods, et al. (In the United States District Court for the Northern District of Oklahoma), Dr. B. Engel, P.E. Professor of Agricultural and Biological Engineering, May 22,2008"
5) E-mail correspondence on Wednesday, August 13, 2008 8:27 AM; From David Page; To Robert George, Louis Bullock, David Riggs, Elizabeth Claire Xidis; Subject, RE: Follow Up Items from July 11 Teleconference with Dr. Engel.
6) Parameter input value ranges set for the automated calibration procedure via the Shuffled Complex Evolution Algorithm (SCE-UA) were extracted from the "SCE.DAT" file in the ILLINOIS, BARRONFORT, and CANEYCREEK sub-folders in the following directory: "N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR"*

Plant Nutrient Parameter Input File for Pasture Land Use (1NP.PAR, 2NP.PAR)
Summary of Original (Initial) Parameter Input Values and Calibrated (Final) Parameter Input Values

Parameter Name	Parameter Description	Unit	Illinois River (Zone 2)[1]		Illinois River (Zone 3)[1]		Baron Fork		Caney Creek		Comment
			Original Input Value	Calibrated Input Value	Original Input Value	Calibrated Input Value	Original Input Value	Calibrated Input Value	Original Input Value	Calibrated Input Value	
AOM	Organic matter content in animal waste.	%	69.5	69.5	69.5	69.5	21.0	21.0	21.0	21.0	All sub-basin parameter input values were calibrated and constrained between 0.12 and 86.0 using an automated calibration.
APHOS	Total phosphorus content in animal waste.	%	1.70	1.70	1.70	1.70	2.35	2.35	2.35	2.35	All sub-basin parameter input values were calibrated and constrained between 1.664 and 2.496 using an automated calibration.
APORGP	Organic phosphorus content in animal waste.	%	0.95	0.95	0.95	0.95	0.97	0.97	0.97	0.97	All sub-basin parameter input values were calibrated and constrained between 0.95 and 0.99 using an automated calibration.
CLABO	Labile phosphorus concentration in each soil horizon. (Number of soil horizons = 5)	ug/g	71.9 68.3 68.2 47.5 43.7	61.7 52.1 45.5 40.7 37.5	133.2 126.6 126.3 88.0 80.9	114.2 96.5 84.3 75.4 69.4	138.6 131.6 130.2 126.4 119.9	61.9 52.3 45.7 40.9 37.6	52.8 50.2 49.7 48.3 45.5	40.0 33.8 29.5 26.4 24.3	Parameter inputs are listed one to five for each soil horizon. Illinois River parameter input values were calibrated and constrained between 100 and 300 using an automated calibration. Baron Fork and Caney Creek parameter input values calibrated and constrained between 80 and 150 using an automated calibration. All sub-basin labile phosphorus input values were manually modified after the automated calibration.
DF	Date of fertilizer application, year of the crop rotation and Julian day.	No Units	1077	1066	1077	1066	1099	1077	1037	1077	Illinois River parameter input values were calibrated and constrained between 60.0 and 300 using an automated calibration. Baron Fork and Caney Creek parameter input values were calibrated and constrained between 100 and 120 using an automated calibration.
RATE	Application rate for animal waste.	tn/ha	0.69	0.50	1.29	0.93	1.04	0.59	0.10	0.10	All sub-basin parameter input values were calibrated and constrained between 0.10 and 1.20 using an automated calibration.
RESDW	Crop residue on the ground surface when simulation begins.	kg/ha	3258.6	3258.6	3258.6	3258.6	4362.3	4362.3	62.3	62.3	All sub-basin parameter input values were calibrated and constrained between 0 and 7,000 using an automated calibration.

Abbreviations:

DF GLEAMS default parameter value applied. This parameter input value was not calibrated for this particular land use.
GN Generic or example value from p.191 of the GLEAMS user manual applied unless noted otherwise. This parameter input value was not calibrated for this particular land use.
NA Not applicable. Parameter input value may not be required if certain model attributes are not selected. For example, parameter inputs required for fertilizer application would not be required if a particular land use or field is not fertilized.

[1]The Illinois River sub-basin is comprised of nutrient loading Zone 2 and Zone 3 (see p. D-17 of Engel's Expert Report). There are separate pasture nutrient input files for Zone 2 and Zone 3. The 1NP.PAR nutrient input file is specified for Zone 2 and the 2NP.PAR file is specified for Zone 3.

Table B-2. Summary of Dr. Engel's Plant Nutrient Parameter Input File for Crop Land Use

Sources of information:

1) GLEAMS original (initial) parameter input values were extracted from the IN.PAR files located in the following directories:*
"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR\ILLINOIS\ORGINPUT
"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR\BARRONFORT\OriginInput
"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR\CANEYCREEK\OriginInput
2) GLEAMS calibrated (final) parameter input values were extracted from the IN.PAR files located in the ILLINOIS, BARRONFORT, and CANEYCREEK sub-folders:*
"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR"*
3) Knisel, W.G. and Davis, F.M. 2000. GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), Version 3.0, User Manual. Pub. No. SEWRL-WGK/FMD-050199.
4) "Expert Report" refers to "Poultry Waste Generation and Land Application in the Illinois River Watershed and Phosphorus Loads to the Illinois River Watershed Streams and Rivers and Lake Tenkiller, Expert Report of Dr. B. Engel, For State of Oklahoma, In Case No. 05-CU-329-GKF-SAJ, State of Oklahoma v. Tyson Foods, et al. (In the United States District Court for the Northern District of Oklahoma), Dr. B. Engel, P.E. Professor of Agricultural and Biological Engineering, May 22,2008"
5) E-mail correspondence on Wednesday, August 13, 2008 8:27 AM; From David Page; To Robert George, Louis Bullock, David Riggs, Elizabeth Claire Xidis; Subject, RE: Follow Up Items from July 11 Teleconference with Dr. Engel.

Plant Nutrient Parameter Input File for Crop Land Use (1NC.PAR)

Summary of Original (Initial) Parameter Input Values and Calibrated (Final) Parameter Input Values

Parameter Name	*Parameter Description*	*Unit*	*Illinois River*		*Baron Fork*		*Caney Creek*		*Comment*
			Original Input Value	*Calibrated Input Value*	*Original Input Value*	*Calibrated Input Value*	*Original Input Value*	*Calibrated Input Value*	
AOM	Organic matter content in animal waste.	%	86.0 86.0	86.0 86.0	86.0 86.0	86.0 86.0	86.0 86.0	86.0 86.0	There are two fertilizer applications of animal waste, which requires two separate parameter input values.
APHOS	Total phosphorus content in animal waste.	%	0.82 0.82	0.82 0.82	0.82 0.82	0.82 0.82	0.82 0.82	0.82 0.82	There are two fertilizer applications of animal waste, which requires two separate parameter input values.
APORGP	Organic phosphorus content in animal waste.	%	0.79 0.79	0.79 0.79	0.79 0.79	0.79 0.79	0.79 0.79	0.79 0.79	There are two fertilizer applications of animal waste, which requires two separate parameter input values.
CLAB()	Labile phosphorus concentration in each soil horizon. (Number of soil horizons = 5)	ug/g	60	60	80	80	60	60	CLAB input values are the same for all soil horizons.
DF	Date of fertilizer application, year of the crop rotation and Julian day.	No Units	1091 1140 2100	1091 1140 2100	1091 1140 2100	1091 1140 2100	1091 1140 2100	1091 1140 2100	There are three fertilizer applications, which requires three separate parameter input values. Two fertilizer applications consist of animal waste and one fertilizer application consists of inorganic commerical fertilizer.
RATE	Application rate for animal waste.	tn/ha	5.00 3.00	5.00 3.00	5.00 3.00	5.00 3.00	5.00 3.00	5.00 3.00	There are two fertilizer applications of animal waste, which requires two separate parameter input values.
RESDW	Crop residue on the ground surface when simulation begins.	kg/ha	DF	DF	DF	DF	DF	DF	

Abbreviations:

DF GLEAMS default parameter value applied. This parameter input value was not calibrated for this particular land use.
GN Generic or example value from p.191 of the GLEAMS user manual applied unless noted otherwise. This parameter input value was not calibrated for this particular land use.
NA Not applicable. Parameter input value may not be required if certain model attributes are not selected. For example, parameter inputs required for fertilizer application would not be required if a particular land use or field is not fertilized.

Table B-3. Summary of Dr. Engel's Plant Nutrient Parameter Input File for Forest Land Use

Sources of information:

1) GLEAMS original (initial) parameter input values were extracted from the IN.PAR files located in the following directories:*
"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR\ILLINOIS\ORGINPUT
"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR\BARRONFORT\OriginInput
"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR\CANEYCREEK\OriginInput
2) GLEAMS calibrated (final) parameter input values were extracted from the IN.PAR files located in the ILLINOIS, BARRONFORT, and CANEYCREEK sub-folders:*
"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR"*
3) Knisel, W.G. and Davis, F.M. 2000. GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), Version 3.0, User Manual. Pub. No. SEWRL-WGK/FMD-050199.
4) "Expert Report" refers to "Poultry Waste Generation and Land Application in the Illinois River Watershed and Phosphorus Loads to the Illinois River Watershed Streams and Rivers and Lake Tenkiller, Expert Report of Dr. B. Engel, For State of Oklahoma, In Case No. 05-CU-329-GKF-SAJ, State of Oklahoma v. Tyson Foods, et al. (In the United States District Court for the Northern District of Oklahoma), Dr. B. Engel, P.E. Professor of Agricultural and Biological Engineering, May 22,2008"
5) E-mail correspondence on Wednesday, August 13, 2008 8:27 AM; From David Page; To Robert George, Louis Bullock, David Riggs, Elizabeth Claire Xidis; Subject, RE: Follow Up Items from July 11 Teleconference with Dr. Engel.

Plant Nutrient Parameter Input File for Forest Land Use (1NF.PAR)
Summary of Original (Initial) Parameter Input Values and Calibrated (Final) Parameter Input Values

Parameter Name	Parameter Description	Unit	Illinois River		Baron Fork		Caney Creek		Comment
			Original Input Value	Calibrated Input Value	Original Input Value	Calibrated Input Value	Original Input Value	Calibrated Input Value	
AOM	Organic matter content in animal waste.	%	NA	NA	NA	NA	NA	NA	
APHOS	Total phosphorus content in animal waste.	%	NA	NA	NA	NA	NA	NA	
APORGP	Organic phosphorus content in animal waste.	%	NA	NA	NA	NA	NA	NA	
CLAB()	Labile phosphorus concentration in each soil horizon. (Number of soil horizons = 5)	ug/g	10	20	30	20	10	25	CLAB input values are the same for all soil horizons. Labile phosphorus input values were manually modified during the calibration process.
DF	Date of fertilizer application, year of the crop rotation and Julian day.	No Units	NA	NA	NA	NA	NA	NA	
RATE	Application rate for animal waste.	tn/ha	NA	NA	NA	NA	NA	NA	
RESDW	Crop residue on the ground surface when simulation begins.	kg/ha	DF	DF	DF	DF	DF	DF	

Abbreviations:

DF GLEAMS default parameter value applied. This parameter input value was not calibrated for this particular land use.
GN Generic or example value from p.191 of the GLEAMS user manual applied unless noted otherwise. This parameter input value was not calibrated for this particular land use.
NA Not applicable. Parameter input value may not be required if certain model attributes are not selected. For example, parameter inputs required for fertilizer application would not be required if a particular land use or field is not fertilized.

Table B-4. Summary of Dr. Engel's Plant Nutrient Parameter Input File for Urban Land Use

Sources of information:

1) GLEAMS original (initial) parameter input values were extracted from the IN.PAR files located in the following directories:*

"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR\ILLINOIS\ORGINPUT

"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR\BARRONFORT\OriginInput

"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR\CANEYCREEK\OriginInput

2) GLEAMS calibrated (final) parameter input values were extracted from the IN.PAR files located in the ILLINOIS, BARRONFORT, and CANEYCREEK sub-folders:*

"N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR"*

3) Knisel, W.G. and Davis, F.M. 2000. GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), Version 3.0, User Manual. Pub. No. SEWRL-WGK/FMD-050199.

4) "Expert Report" refers to "Poultry Waste Generation and Land Application in the Illinois River Watershed and Phosphorus Loads to the Illinois River Watershed Streams and Rivers and Lake Tenkiller, Expert Report of Dr. B. Engel, For State of Oklahoma, In Case No. 05-CU-329-GKF-SAJ, State of Oklahoma v. Tyson Foods, et al. (In the United States District Court for the Northern District of Oklahoma), Dr. B. Engel, P.E. Professor of Agricultural and Biological Engineering, May 22,2008"

5) E-mail correspondence on Wednesday, August 13, 2008 8:27 AM; From David Page; To Robert George, Louis Bullock, David Riggs, Elizabeth Claire Xidis; Subject, RE: Follow Up Items from July 11 Teleconference with Dr. Engel.

Plant Nutrient Parameter Input File for Urban Land Use (1NU.PAR)

Summary of Original (Initial) Parameter Input Values and Calibrated (Final) Parameter Input Values

Parameter Name	Parameter Description	Unit	Illinois River		Baron Fork		Caney Creek		Comment
			Original Input Value	Calibrated Input Value	Original Input Value	Calibrated Input Value	Original Input Value	Calibrated Input Value	
AOM	Organic matter content in animal waste.	%	NA	NA	NA	NA	NA	NA	
APHOS	Total phosphorus content in animal waste.	%	NA	NA	NA	NA	NA	NA	
APORGP	Organic phosphorus content in animal waste.	%	NA	NA	NA	NA	NA	NA	
CLAB()	Labile phosphorus concentration in each soil horizon. (Number of soil horizons = 5)	ug/g	DF	DF	DF	DF	DF	DF	
DF	Date of fertilizer application, year of the crop rotation and Julian day.	No Units	NA	NA	NA	NA	NA	NA	
RATE	Application rate for animal waste.	tn/ha	NA	NA	NA	NA	NA	NA	
RESDW	Crop residue on the ground surface when simulation begins.	kg/ha	DF	DF	DF	DF	DF	DF	

Abbreviations:

DF GLEAMS default parameter value applied. This parameter input value was not calibrated for this particular land use.

GN Generic or example value from p.191 of the GLEAMS user manual applied unless noted otherwise. This parameter input value was not calibrated for this particular land use.

NA Not applicable. Parameter input value may not be required if certain model attributes are not selected. For example, parameter inputs required for fertilizer application would not be required if a particular land use or field is not fertilized.

Table B-5. Dr. Engel's Plant Nutrient Parameter Input Files for Pasture Land Use

Sources of information:

1) GLEAMS parameter input values were extracted from the 1N.PAR files and 2NP.PAR files located in the ILLINOIS, BARRONFORT, and CANEYCREEK sub-folders in the following directory: "N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR*"*

2) Knisel, W.G. and Davis, F.M. 2000. GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), Version 3.0, User Manual. Pub. No. SEWRL-WGK/FMD-050199.

3) "Expert Report" refers to "Poultry Waste Generation and Land Application in the Illinois River Watershed and Phosphorus Loads to the Illinois River Watershed Streams and Rivers and Lake Tenkiller, Expert Report of Dr. B. Engel, For State of Oklahoma, In Case No. 05-CU-329-GKF-SAJ, State of Oklahoma v. Tyson Foods, et al. (In the United States District Court for the Northern District of Oklahoma), Dr. B. Engel, P.E. Professor of Agricultural and Biological Engineering, May 22,2008"

4) E-mail correspondence on Wednesday, August 13, 2008 8:27 AM: From David Page; To Robert George, Louis Bullock, David Riggs, Elizabeth Claire Xidis; Subject, RE: Follow Up Items from July 11 Teleconference with Dr. Engel.

5) Parameter input value ranges set for the automated calibration procedure via the Shuffled Complex Evolution Algorithm (SCE-UA) were extracted from the "SCE.DAT" file in the ILLINOIS, BARRONFORT, and CANEYCREEK sub-folders in the following directory: "N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR"*

Plant Nutrient Parameter Input File for Pasture Land Use (1NP.PAR, 2NP.PAR)

Card #	Parameter Name	Parameter Description	Unit	Parameter Value: Illinois River (Zone 2)[1]	Illinois River (Zone 3)[1]	Baron Fork	Caney Creek	Source of Parameter Value	Comment
1-3	TITLE	Three 80-character lines of alphanumeric information that identifies the particular computer run. For example, the soil type, the crop rotation, the tillage practices, may be useful in identifying the file and specific GLEAMS application.	No Units					GN	The run description does not provide any information regarding the site-specific application to the IRW. The run description is a generic description that was taken from an example input file on p. 189 of the GLEAMS user manual.
4	NBYR	Beginning year of plant nutrient simulation.	Year	1901	1901	1901	1901	AS	
4	NEYR	Ending year of plant nutrient simulation.	Year	2000	2000	2000	2000	AS	
4	NUTOUT	Code to designate level of printed nutrient output.	No Units	2	2	2	2	AS	
4	FLGROT	Number of years in a crop rotation cycle.	No Units	1	1	1	1	AS	
4	FLGBAL	Code for output of N and P balance at the end each year of simulation.	No Units	0	0	0	0	AS	
5	RESDW	Crop residue on the ground surface when simulation begins.	kg/ha	3258.6	3258.6	4362.3	62.3	CAL	All sub-basin parameter input values were calibrated and constrained between 0 and 7,000 using an automated calibration.
5	RCN	Nitrogen concentration in rainfall.	ppm	0.8	0.8	0.8	0.8	GN	
5	CNI	Concentration of nitrate-nitrogen in irrigation.	ppm					DF	
5	CPI	Concentration of labile-phosphorus in irrigation.	ppm					DF	
6	TN0	Total nitrogen in each soil horizon. (Number of soil horizons = 5)	%	0.055 0.055 0.043 0.043 0.021	0.055 0.055 0.043 0.043 0.021	0.055 0.055 0.043 0.043 0.021	0.055 0.055 0.043 0.043 0.021	GN	Parameter inputs are listed one to five for each soil horizon.
7	CNIT0	Nitrate-nitrogen concentration in each soil horizon. (Number of soil horizons = 5)	ug/g	10 10 7.0 7.0 3.0	10 10 7.0 7.0 3.0	10 10 7.0 7.0 3.0	10 10 7.0 7.0 3.0	GN	Parameter inputs are listed one to five for each soil horizon.
8	POTMN0	Potentially mineralizable nitrogen in each soil horizon. (Number of soil horizons = 5)	kg/ha	150.0 150.0 230.0 230.0 115.0	150.0 150.0 230.0 230.0 115.0	150.0 150.0 230.0 230.0 115.0	150.0 150.0 230.0 230.0 115.0	GN	Parameter inputs are listed one to five for each soil horizon.
9	ORGNW	Organic nitrogen content from animal waste in the plow horizon.	%	0	0	0	0	GN	
10	TP0	Total phosphorus in each soil horizon. (Number of soil horizons= 5)	%					DF	
11	CLAB0	Labile phosphorus concentration in each soil horizon. (Number of soil horizons = 5)	ug/g	61.7 52.1 45.5 40.7 37.5	114.2 96.5 84.3 75.4 69.4	61.9 52.3 45.7 40.9 37.6	40.0 33.8 29.5 26.4 24.3	CAL	Parameter inputs are listed one to five for each soil horizon. Illinois River parameter input values were calibrated and constrained between 100 and 300 using an automated calibration. Baron Fork and Caney Creek parameter input values calibrated and constrained between 80 and 150 using an automated calibration. All sub-basin labile phosphorus input values were manually modified after the automated calibration.
12	ORGPW	Organic P content from animal waste in plow horizon.	%	0	0	0	0	GN	
13	PDATE	Date that the following parameters are valid, year of the crop rotation cycle and Julian day.	No Units	1001	1001	1001	1001	AS	
14	NF	Number of fertilizer and animal waste applications during the update period.	No Units	1	1	1	1	AS	
14	NTIL	Number of tillage operations during the update period.	No Units	0	0	0	0	AS	
14	DHRVST	Date of crop harvest, year of the crop rotation cycle and Julian day.	No Units	1310	1310	1310	1310	SS	
15	ICROP	Identification number of the crop grown during this cropping period.	No Units	2	2	2	2	SS	Alfalfa-hay is the crop type specified.
15	LEG	Code for legume crop.	No Units	0	0	0	0	DF	
15	PY	Potential yield for the harvestable portion of the crop.	kg/ha	4500	4500	4500	4500	DF	
15	DMY	Dry matter ratio, the ratio of total dry matter production to harvestable portion of the crop.	No Units					DF	
15	CNR	Carbon nitrogen ratio for the crop.	No Units					DF	
15	RNP	Ratio of crop nitrogen to phosphorus.	No Units					DF	
15	C1	Coefficient in the exponential relation to estimate nitrogen content of the crop.	No Units					DF	
15	C2	Exponent in the exponential relation to estimate nitrogen content of the crop.	No Units					DF	
16	DF	Date of fertilizer application, year of the crop rotation and Julian day.	No Units	1066	1066	1077	1077	CAL	Illinois River parameter input values were calibrated and constrained between 60.0 and 300 using an automated calibration. Baron Fork and Caney Creek parameter input values were calibrated and constrained between 100 and 120 using an automated calibration.
16	MFERT	Code for method of fertilization.	No Units	1	1	1	1	AS	Code = 1 indicates that an organic (animal waste or sewage sludge) is applied.
16	METHAP	Code for method of application.	No Units	0	0	0	0	AS	Code = 0 denotes surface application of fertilizer or animal waste.
16	MTYPE	Code for animal waste type.	No Units	15	15	15	15	AS	Code = 15 indicates that the user specifies total N and P, organic N and P, ammonia and soluble phosphorus in animal waste.
17	FN	Fertilizer nitrate.	kg/ha					NA	Card 17 is skipped if animal waste is applied.
17	FNH	Fertilizer ammonia.	kg/ha					NA	Card 17 is skipped if animal waste is applied.
17	FP	Fertilizer phosphorus.	kg/ha					NA	Card 17 is skipped if animal waste is applied.
17	DEPIN	Depth of incorporation.	cm					NA	Card 17 is skipped if animal waste is applied.
17	FRTWAT	Depth of water applied for fertigation.	cm					NA	Card 17 is skipped if animal waste is applied.
18	RATE	Application rate for animal waste.	t/ha	0.50	0.93	0.59	0.1	CAL	All sub-basin parameter input values were calibrated and constrained between 0.10 and 1.20 using an automated calibration.
18	DEPIN	Depth of incorporation.	cm	0	0	0	0	GN	
18	ATN	Total nitrogen in animal waste.	%	2.81	2.81	2.81	2.81	GN	
18	APORGN	Organic nitrogen content in animal waste.	%	2.08	2.08	2.08	2.08	GN	
18	ANH	Ammonia content in animal waste.	%	0.72	0.72	0.72	0.72	GN	
18	APHOS	Total phosphorus content in animal waste.	%	1.70	1.70	2.35	2.35	CAL	All sub-basin parameter input values were calibrated and constrained between 1.664 and 2.496 using an automated calibration.
18	APORGP	Organic phosphorus content in animal waste.	%	0.95	0.95	0.97	0.97	CAL	All sub-basin parameter input values were calibrated and constrained between 0.95 and 0.99 using an automated calibration.
18	AOM	Organic matter content in animal waste.	%	69.5	69.5	21.0	21.0	CAL	All sub-basin parameter input values were calibrated and constrained between 0.12 and 86.0 using an automated calibration.
18	WASTYP	Type of animal waste (e.g., solid, slurry, or liquid).	No Units	1	1	1	1	AS	Code = 1 denotes that waste is in solid form.
19	NTDAY	Date of tillage, year of crop rotation cycle and Julian day.	No Units					NA	
19	LTIL	Code to designate the tillage implement or equipment used.	No Units					NA	
19	DTIL	Depth of tillage.	cm					NA	
19	EFFINC	Efficiency of incorporation of surface residue.	No Units					NA	
19	FMIX	Tillage mixing efficiency.	No Units					NA	

Abbreviations:

AS Application specific parameter value applied to set simulation time periods, output preferences, and parameter codes for particular method applications (e.g., method of fertilization).
DF GLEAMS default parameter value applied.
CAL Calibrated parameter value applied.
GN Generic or example value from p. 189 of the GLEAMS user manual applied unless noted otherwise.
NA Not applicable. Parameter input value may not be required if certain model attributes are not selected. For example, parameter inputs required for fertilizer application would not be required if a particular land use or field is not fertilized.
SS Site-specific parameter value applied.

[1] The Illinois River sub-basin is comprised of nutrient loading Zone 2 and Zone 3 (see p. D-17 of Engel's Expert Report). There are separate pasture nutrient input files for Zone 2 and Zone 3. The 1NP.PAR nutrient input file is specified for Zone 2 and the 2NP.PAR file is specified for Zone 3.

Table B-6. Dr. Engel's Plant Nutrient Parameter Input File for Crop Land Use

Sources of information:
1) GLEAMS parameter input values were extracted from the INP.PAR files located in the ILLINOIS, BARONFORK, and CANEYCREEK sub-folders in the following directory: "N:\IRWLAW\Expert_Reports\EngelModels\Gleams_Final\1 FUTURE_300TR"
2) Knisel, W.G. and Davis, F.M. 2000. GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), Version 3.0, User Manual. Pub. No. SEWRL-WGK/FMD-050199.
3) "Expert Report" refers to "Poultry Waste Generation and Land Application in the Illinois River Watershed and Phosphorus Loads to the Illinois River Watershed Streams and Rivers and Lake Tenkiller, Expert Report of Dr. B. Engel, For State of Oklahoma, In Case No. 05-CV-329-GKF-SAJ, State of Oklahoma v. Tyson Foods, et al. In the United States District Court for the Northern District of Oklahoma, Dr. B. Engel, P.E. Professor of Agricultural and Biological Engineering, May 22,2008"
4) E-mail correspondence on Wednesday, August 13, 2008 8:37 AM, From David Page; To Robert George, Louis Bullock, David Riggs, Elizabeth Claire Xidis; Subject: RE: Follow Up Items from July 11 Teleconference with Dr. Engel

Plant Nutrient Parameter Input File for Crop Land Use (INC.PAR)

Card#	Parameter Name	Parameter Description	Unit	Parameter Value: Illinois River	Parameter Value: Baron Fork	Parameter Value: Caney Creek	Source of Parameter Value	Comment
1-3	*TITLE*	Three 80-character lines of alphanumeric information that identifies the particular computer run. For example, the soil type, the crop rotation, the tillage practices, may be useful in identifying the file and results GLEAMS application.	No Units				GN	The run description does not provide any information regarding the site-specific application to the IRW. The run description is a generic description that was taken from an example input file on p. 190 of the GLEAMS user manual.
4	*BGNYR*	Beginning year of plant nutrient simulation.	Year	1991	1991	1991	AS	
4	*ENDYR*	Ending year of plant nutrient simulation.	Year	2009	2009	2009	AS	
4	*NUTOUT*	Code to designate level of printed nutrient output.	No Units	1	2	1	AS	
4	*YLDROT*	Number of years in a crop rotation cycle.	No Units	1	1	1	AS	
4	*PLNBAL*	Code for output of N and P balance at the end each year of simulation.	No Units	0	0	0	AS	
5	*RESIDW*	Crop residue on the ground surface when simulation begins.	kg/ha				DF	
5	*RCN*	Nitrogen concentration in rainfall.	ppm				DF	
5	*CNI*	Concentration of nitrate-nitrogen in irrigation.	ppm				DF	
5	*CPI*	Concentration of labile phosphorus in irrigation.	ppm				DF	
6	*TNS*	Total nitrogen in each soil horizon. (Number of soil horizons = 5)	%				DF	
7	*CNO3S*	Nitrate-nitrogen concentration in each soil horizon. (Number of soil horizons = 5)	mg/g				DF	
8	*POTMNQ*	Potentially mineralizable nitrogen in each soil horizon. (Number of soil horizons = 5)	kg/ha				DF	
9	*ORGNW*	Organic nitrogen content from animal waste in the plow horizon.	%				DF	
10	*TPS*	Total phosphorus in each soil horizon. (Number of soil horizons = 5)	%				DF	
11	*CLABS*	Labile phosphorus concentration in each soil horizon. (Number of soil horizons = 5)	mg/g	60	60	60	CAL	CLAB input values are the same for all soil horizons. Labile phosphorus input values were manually modified during the calibration process.
12	*ORGPW*	Organic P content from animal waste in plow horizon.	%				DF	
The following input section includes parameter input values for a corn-grain crop with two animal waste fertilizer applications.								
13	*PDATE*	Date that the following parameters are valid, year of the crop rotation cycle and Julian day.	No Units	1001	1001	1001	GN	
14	*NF*	Number of fertilizer and animal waste applications during the update period.	No Units	2	2	2	GN	
14	*NTIL*	Number of tillage operations during the update period.	No Units	3	3	3	GN	
14	*DAHRVT*	Date of crop harvest, year of the crop rotation cycle and Julian day.	No Units	1244	1244	1244	GN	
15	*ICROP*	Identification number of the crop grown during this update period.	No Units	20	20	20	GN	Corn-grain is the crop type specified.
15	*LEG*	Code for legume crop.	No Units				DF	
15	*PY*	Potential yield for the harvestable portion of the crop.	kg/ha				DF	
15	*DMY*	Dry matter ratio, the ratio of total dry matter production to harvestable portion of the crop.	No Units				DF	
15	*CNR*	Carbon:nitrogen ratio for the crop.	No Units				DF	
15	*RNP*	Ratio of crop nitrogen to phosphorus.	No Units				DF	
15	*C1*	Coefficient in the exponential relation to estimate nitrogen content of the crop.	No Units				DF	
15	*C2*	Exponent in the exponential relation to estimate nitrogen content of the crop.	No Units				DF	
16	*DF*	Date of fertilizer application, year of the crop rotation and Julian day.	No Units	1091 1140	1091 1140	1091 1140	GN	There are two fertilizer applications of animal waste. The first DF (1091) is for the first application and the second DF (1140) is for the second application. Note that each subsequent input parameter value will have two inputs, one for each fertilizer application.
16	*MFERT*	Code for method of fertilization.	No Units	1 1	1 1	1 1	GN	Code = 1 indicates that an organic (animal waste or sewage sludge) is applied.
16	*METHAP*	Code the method of application.	No Units	1 0	1 0	1 0	GN	Code = 1 denotes incorporated fertilizer or animal waste. Code = 0 denotes surface application of fertilizer or animal waste.
16	*MTYPE*	Code for animal waste type.	No Units	1 1	1 1	1 1	GN	Code = 1 indicates that dairy cattle animal waste in solid form is applied.
17	*FN*	Fertilizer nitrate.	kg/ha				NA	Card 17 is skipped if animal waste is applied.
17	*FNH*	Fertilizer ammonia.	kg/ha				NA	Card 17 is skipped if animal waste is applied.
17	*FP*	Fertilizer phosphorus.	kg/ha				NA	Card 17 is skipped if animal waste is applied.
17	*DEPTH*	Depth of incorporation.	cm				NA	Card 17 is skipped if animal waste is applied.
17	*FRTWAT*	Depth of water applied for fertigation.	cm				NA	Card 17 is skipped if animal waste is applied.
18	*RATE*	Application rate for animal waste.	t/ha	5.00 5.00	5.00 5.00	5.00 5.00	GN	
18	*DEPTH*	Depth of incorporation.	cm	10 0	10 0	10 0	GN	
18	*ATN*	Total nitrogen in animal waste.	%	4.40 4.40	4.40 4.40	4.40 4.40	GN	
18	*APORGN*	Organic nitrogen content in animal waste.	%	3.32 3.32	3.32 3.32	3.32 3.32	GN	
18	*AMN*	Ammonia content in animal waste.	%	1.06 1.06	1.06 1.06	1.06 1.06	GN	
18	*APHOS*	Total phosphorus content in animal waste.	%	0.82 0.82	0.82 0.82	0.82 0.82	GN	
18	*APORGP*	Organic phosphorus content in animal waste.	%	0.79 0.79	0.79 0.79	0.79 0.79	GN	
18	*AOM*	Organic matter content in animal waste.	%	86.0 86.0	86.0 86.0	86.0 86.0	GN	
18	*WASTTP*	Type of animal waste (e.g., solid, slurry, or liquid).	No Units	1 1	1 1	1 1	GN	Code = 1 denotes that waste is in solid form.
19	*NTDAY*	Date of tillage, year of crop rotation cycle and Julian day	No Units	1091 1091 1255	1091 1091 1255	1091 1091 1255	GN	These entries are specified for three separate tillage operations. The first NTDAY (1091) is for the first tillage operation, the second NTDAY (1091) is for the second tillage operation, and the third NTDAY (1255) is for the third tillage operation. Note that each subsequent input parameter value will have three inputs, one for each tillage operation.
19	*LTIL*	Code to designate the tillage implement or equipment used.	No Units	16 22 10	16 22 10	16 22 10	GN	
19	*DTIL*	Depth of tillage.	cm	10 4 15	10 4 15	10 4 15	GN	
19	*EFFINC*	Efficiency of incorporation of surface residue.	No Units				DF	
19	*FMIX*	Tillage mixing efficiency.	No Units				DF	
The following input section includes parameter input values for soybeans only with one commercial fertilizer application.								
13	*PDATE*	Date that the following parameters are valid, year of the crop rotation cycle and Julian day.	No Units	2001	2001	2001	GN	
14	*NF*	Number of fertilizer and animal waste applications during the update period.	No Units	1	1	1	GN	
14	*NTIL*	Number of tillage operations during the update period.	No Units	3	3	3	GN	
14	*DAHRVT*	Date of crop harvest, year of the crop rotation cycle and Julian day.	No Units	2300	2300	2300	GN	
15	*ICROP*	Identification number of the crop grown during this update period.	No Units	58	58	58	GN	Soybeans-row crop is the crop type specified.
15	*LEG*	Code for legume crop.	No Units				DF	
15	*PY*	Potential yield for the harvestable portion of the crop.	kg/ha				DF	
15	*DMY*	Dry matter ratio, the ratio of total dry matter production to harvestable portion of the crop.	No Units				DF	
15	*CNR*	Carbon:nitrogen ratio for the crop.	No Units				DF	
15	*RNP*	Ratio of crop nitrogen to phosphorus.	No Units				DF	
15	*C1*	Coefficient in the exponential relation to estimate nitrogen content of the crop.	No Units				DF	
15	*C2*	Exponent in the exponential relation to estimate nitrogen content of the crop.	No Units				DF	
16	*DF*	Date of fertilizer application, year of the crop rotation and Julian day.	No Units	2100	2100	2100	GN	There are two fertilizer applications of animal waste. The first DF (1091) is for the first application and the second DF (1140) is for the second application.
16	*MFERT*	Code for method of fertilization.	No Units	0	0	0	GN	Code = 0 indicates that an inorganic (commercial) fertilizer is applied.
16	*METHAP*	Code for method of application.	No Units	1	1	1	GN	Code = 1 denotes incorporated fertilizer or animal waste.
16	*MTYPE*	Code for animal waste type.	No Units				NA	
17	*FN*	Fertilizer nitrate.	kg/ha	0	0	0	GN	
17	*FNH*	Fertilizer ammonia.	kg/ha	33	33	33	GN	
17	*FP*	Fertilizer phosphorus.	kg/ha	45	45	45	GN	
17	*DEPTH*	Depth of incorporation.	cm	10	10	10	GN	
17	*FRTWAT*	Depth of water applied for fertigation.	cm				DF	
18	*RATE*	Application rate for animal waste.	t/ha				NA	Card 18 is skipped if commercial fertilizer is applied.
18	*DEPTH*	Depth of incorporation.	cm				NA	Card 18 is skipped if commercial fertilizer is applied.
18	*ATN*	Total nitrogen in animal waste.	%				NA	Card 18 is skipped if commercial fertilizer is applied.
18	*APORGN*	Organic nitrogen content in animal waste.	%				NA	Card 18 is skipped if commercial fertilizer is applied.
18	*AMN*	Ammonia content in animal waste.	%				NA	Card 18 is skipped if commercial fertilizer is applied.
18	*APHOS*	Total phosphorus content in animal waste.	%				NA	Card 18 is skipped if commercial fertilizer is applied.
18	*APORGP*	Organic phosphorus content in animal waste.	%				NA	Card 18 is skipped if commercial fertilizer is applied.
18	*AOM*	Organic matter content in animal waste.	%				NA	Card 18 is skipped if commercial fertilizer is applied.
18	*WASTTP*	Type of animal waste (e.g., solid, slurry, or liquid).	No Units				NA	Card 18 is skipped if commercial fertilizer is applied.
19	*NTDAY*	Date of tillage, year of crop rotation cycle and Julian day.	No Units	2100 2100 2305	2100 2100 2305	2100 2100 2305	GN	These entries are specified for three separate tillage operations. The first NTDAY (2100) is for the first tillage operation, the second NTDAY (2100) is for the second tillage operation, and the third NTDAY (2305) is for the third tillage operation. Note that each subsequent input parameter value will have three inputs, one for each tillage operation.
19	*LTIL*	Code to designate the tillage implement or equipment used.	No Units	4 23 10	4 23 10	4 23 10	GN	
19	*DTIL*	Depth of tillage.	cm	15 4 15	15 4 15	15 4 15	GN	
19	*EFFINC*	Efficiency of incorporation of surface residue.	No Units				DF	
19	*FMIX*	Tillage mixing efficiency.	No Units				DF	

Abbreviations:

AS	Application specific parameter value applied to set simulation time periods, output preferences, and parameter codes for particular method applications (e.g., method of fertilization).
DF	GLEAMS default parameter value applied.
CAL	Calibrated parameter value applied.
GN	Generic or example value from p. 190 of the GLEAMS user manual applied unless noted otherwise.
NA	Not applicable. Parameter input value may not be required if certain model attributes are not selected. For example, parameter inputs required for fertilizer application would not be required if a particular land use or field is not fertilized.
SS	Site-specific parameter value applied.

Table B-7. Dr. Engel's Plant Nutrient Parameter Input File for Forest Land Use

Sources of information:

1) GLEAMS parameter input values were extracted from the 1N.PAR files located in the ILLINOIS, BARRONFORT, and CANEYCREEK sub-folders in the following directory: "N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1.FUTURE_100YR*"*

2) Knisel, W.G. and Davis, F.M. 2000. GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), Version 3.0. User Manual. Pub. No. SEWRL-WGK/FMD-050199.

3) "Expert Report" refers to "Poultry Waste Generation and Land Application in the Illinois River Watershed and Phosphorus Loads to the Illinois River Watershed Streams and Rivers and Lake Tenkiller, Expert Report of Dr. B. Engel, For State of Oklahoma, In Case No. 05-CU-329-GKF-SAJ, State of Oklahoma v. Tyson Foods, et al. (In the United States District Court for the Northern District of Oklahoma), Dr. B. Engel, P.E. Professor of Agricultural and Biological Engineering, May 22, 2008"

4) E-mail correspondence on Wednesday, August 13, 2008 8:27 AM; From David Page; To Robert George, Louis Bullock, David Riggs, Elizabeth Claire Xidis; Subject, RE: Follow Up Items from July 11 Teleconference with Dr. Engel.

Plant Nutrient Parameter Input File for Forest Land Use (1NF.PAR)

Card #	Parameter Name	Parameter Description	Unit	Parameter Value			Source of Parameter Value	Comment
				Illinois River	Baron Fork	Caney Creek		
1-3	TITLE	Three 80-character lines of alphanumeric information that identifies the particular computer run. For example, the soil type, the crop rotation, the tillage practices, may be useful in identifying the file and specific GLEAMS application.	No Units				GN	The run description does not provide any information regarding the site-specific application to the IRW. The run description is a generic description that was taken from an example input file on p. 189 of the GLEAMS user manual.
4	NBYR	Beginning year of plant nutrient simulation.	Year	1901	1901	1901	AS	
4	NEYR	Ending year of plant nutrient simulation.	Year	2000	2000	2000	AS	
4	NUTOUT	Code to designate level of printed nutrient output.	No Units	2	2	2	AS	
4	FLGROT	Number of years in a crop rotation cycle.	No Units	1	1	1	AS	
4	FLGBAL	Code for output of N and P balance at the end each year of simulation.	No Units	0	0	0	AS	
5	RESDW	Crop residue on the ground surface when simulation begins.	kg/ha				DF	
5	RCN	Nitrogen concentration in rainfall.	ppm				DF	
5	CNI	Concentration of nitrate-nitrogen in irrigation.	ppm				DF	
5	CPI	Concentration of labile-phosphorus in irrigation.	ppm				DF	
6	TN0	Total nitrogen in each soil horizon. (Number of soil horizons = 5)	%				DF	
7	CNIT0	Nitrate-nitrogen concentration in each soil horizon. (Number of soil horizons = 5)	ug/g				DF	
8	POTMN0	Potentially mineralizable nitrogen in each soil horizon. (Number of soil horizons = 5)	kg/ha				DF	
9	ORGNW	Organic nitrogen content from animal waste in the plow horizon.	%				DF	
10	TP0	Total phosphorus in each soil horizon. (Number of soil horizons= 5)	%				DF	
11	CLAB0	Labile phosphorus concentration in each soil horizon. (Number of soil horizons = 5)	ug/g	20	20	25	CAL	CLAB input values are the same for all soil horizons. Labile phosphorus input values were manually modified during the calibration process.
12	ORGPW	Organic P content from animal waste in plow horizon.	%				DF	
13	PDATE	Date that the following parameters are valid, year of the crop rotation cycle and Julian day.	No Units	1001	1001	1001	GN	
14	NF	Number of fertilizer and animal waste applications during the update period.	No Units				DF	
14	NTIL	Number of tillage operations during the update period.	No Units				DF	
14	DHRVST	Date of crop harvest, year of the crop rotation cycle and Julian day.	No Units				DF	
15	ICROP	Identification number of the crop grown during this cropping period.	No Units	69	69	69	GN	Trees-conifer is the crop type specified.
15	LEG	Code for legume crop.	No Units				DF	
15	PY	Potential yield for the harvestable portion of the crop.	kg/ha				DF	
15	DMY	Dry matter ratio, the ratio of total dry matter production to harvestable portion of the crop.	No Units				DF	
15	CNR	Carbon:nitrogen ratio for the crop.	No Units				DF	
15	RNP	Ratio of crop nitrogen to phosphorus.	No Units				DF	
15	C1	Coefficient in the exponential relation to estimate nitrogen content of the crop.	No Units				DF	
15	C2	Exponent in the exponential relation to estimate nitrogen content of the crop.	No Units				DF	
16	DF	Date of fertilizer application, year of the crop rotation and Julian day.	No Units				NA	
16	MFERT	Code for method of fertilization.	No Units				NA	
16	METHAP	Code for method of application.	No Units				NA	
16	MTYPE	Code for animal waste type.	No Units				NA	
17	FN	Fertilizer nitrate.	kg/ha				NA	
17	FNH	Fertilizer ammonia.	kg/ha				NA	
17	FP	Fertilizer phosphorus.	kg/ha				NA	
17	DEPIN	Depth of incorporation.	cm				NA	
17	FRTWAT	Depth of water applied for fertigation.	cm				NA	
18	RATE	Application rate for animal waste.	to/ha				NA	
18	DEPIN	Depth of incorporation.	cm				NA	
18	ATN	Total nitrogen in animal waste.	%				NA	
18	APORGN	Organic nitrogen content in animal waste.	%				NA	
18	ANH	Ammonia content in animal waste.	%				NA	
18	APHOS	Total phosphorus content in animal waste.	%				NA	
18	APORGP	Organic phosphorus content in animal waste.	%				NA	
18	AOM	Organic matter content in animal waste.	%				NA	
18	WASTYP	Type of animal waste (e.g., solid, slurry, or liquid).	No Units				NA	
19	NTDAY	Date of tillage, year of crop rotation cycle and Julian day.	No Units				NA	
19	LTIL	Code to designate the tillage implement or equipment used.	No Units				NA	
19	DTIL	Depth of tillage.	cm				NA	
19	EFFINC	Efficiency of incorporation of surface residue.	No Units				NA	
19	FMIX	Tillage mixing efficiency.	No Units				NA	

Abbreviations:

AS Application specific parameter value applied to set simulation time periods, output preferences, and parameter codes for particular method applications (e.g., method of fertilization).
DF GLEAMS default parameter value applied.
CAL Calibrated parameter value applied.
GN Generic or example value from p.191 of the GLEAMS user manual applied unless noted otherwise.
NA Not applicable. Parameter input value may not be required if certain model attributes are not selected. For example, parameter inputs required for fertilizer application would not be required if a particular land use or field is not fertilized.
SS Site-specific parameter value applied.

Table B-8. Dr. Engel's Plant Nutrient Parameter Input File for Urban Land Use

Sources of information:

1) GLEAMS parameter input values were extracted from the IN.PAR files located in the ILLINOIS, BARRONFORT, and CANEYCREEK sub-folders in the following directory: "N:\IRWLAW1\Expert_Reports\Engel\Materials\Gleams_Final\1.1FUTURE_100YR*"*

2) Knisel, W.G. and Davis, F.M. 2000. GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), Version 3.0, User Manual. Pub. No. SEWRL-WGK/FMD-050199.

3) "Expert Report" refers to "Poultry Waste Generation and Land Application in the Illinois River Watershed and Phosphorus Loads to the Illinois River Watershed Streams and Rivers and Lake Tenkiller, Expert Report of Dr. B. Engel, For State of Oklahoma, In Case No. 05-CU-329-GKF-SAJ, State of Oklahoma v. Tyson Foods, et al. (In the United States District Court for the Northern District of Oklahoma), Dr. B. Engel, P.E. Professor of Agricultural and Biological Engineering, May 22, 2008"

4) E-mail correspondence on Wednesday, August 13, 2008 8:27 AM; From David Page; To Robert George, Louis Bullock, David Riggs, Elizabeth Claire Xidis; Subject, RE: Follow Up Items from July 11 Teleconference with Dr. Engel.

Plant Nutrient Parameter Input File for Urban Land Use (1NU.PAR)

Card #	Parameter Name	Parameter Description	Unit	Parameter Value			Source of Parameter Value	Comment
				Illinois River	Baron Fork	Caney Creek		
1-3	*TITLE*	Three 80-character lines of alphanumeric information that identifies the particular computer run. For example, the soil type, the crop rotation, the tillage practices, may be useful in identifying the file and specific GLEAMS application.	No Units				GN	The run description does not provide any information regarding the site-specific application to the IRW. The run description is a generic description that was taken from an example input file on p. 189 of the GLEAMS user manual.
4	*NBYR*	Beginning year of plant nutrient simulation.	Year	1901	1901	1901	AS	
4	*NEYR*	Ending year of plant nutrient simulation.	Year	2000	2000	2000	AS	
4	*NUTOUT*	Code to designate level of printed nutrient output.	No Units	2	2	2	AS	
4	*FLGROT*	Number of years in a crop rotation cycle.	No Units	1	1	1	AS	
4	*FLGBAL*	Code for output of N and P balance at the end each year of simulation.	No Units	0	0	0	AS	
5	*RESDW*	Crop residue on the ground surface when simulation begins.	kg/ha				DF	
5	*RCN*	Nitrogen concentration in rainfall.	ppm				DF	
5	*CNI*	Concentration of nitrate-nitrogen in irrigation.	ppm				DF	
5	*CPI*	Concentration of labile-phosphorus in irrigation.	ppm				DF	
6	*TN0*	Total nitrogen in each soil horizon. (Number of soil horizons = 5)	%				DF	
7	*CNIT0*	Nitrate-nitrogen concentration in each soil horizon. (Number of soil horizons = 5)	ug/g				DF	
8	*POTMN0*	Potentially mineralizable nitrogen in each soil horizon. (Number of soil horizons = 5)	kg/ha				DF	
9	*ORGNW*	Organic nitrogen content from animal waste in the plow horizon.	%				DF	
10	*TP0*	Total phosphorus in each soil horizon. (Number of soil horizons= 5)	%				DF	
11	*CLAB0*	Labile phosphorus concentration in each soil horizon. (Number of soil horizons = 5)	ug/g				DF	
12	*ORGPW*	Organic P content from animal waste in plow horizon.	%				DF	
13	*PDATE*	Date that the following parameters are valid, year of the crop rotation cycle and Julian day.	No Units	1001	1001	1001	GN	
14	*NF*	Number of fertilizer and animal waste applications during the update period.	No Units	0	0	0	GN	
14	*NTIL*	Number of tillage operations during the update period.	No Units	0	0	0	GN	
14	*DHRVST*	Date of crop harvest, year of the crop rotation cycle and Julian day.	No Units	10366	10366	10366	AS	
15	*ICROP*	Identification number of the crop grown during this cropping period.	No Units	2	2	2	AS	Alfalfa-hay is the crop type specified.
15	*LEG*	Code for legume crop.	No Units				DF	
15	*PY*	Potential yield for the harvestable portion of the crop.	kg/ha				DF	
15	*DMY*	Dry matter ratio, the ratio of total dry matter production to harvestable portion of the crop.	No Units				DF	
15	*CNR*	Carbon:nitrogen ratio for the crop.	No Units				DF	
15	*RNP*	Ratio of crop nitrogen to phosphorus.	No Units				DF	
15	*C1*	Coefficient in the exponential relation to estimate nitrogen content of the crop.	No Units				DF	
15	*C2*	Exponent in the exponential relation to estimate nitrogen content of the crop.	No Units				DF	
16	*DF*	Date of fertilizer application, year of the crop rotation and Julian day.	No Units				NA	
16	*MFERT*	Code for method of fertilization.	No Units				NA	
16	*METHAP*	Code for method of application.	No Units				NA	
16	*MTYPE*	Code for animal waste type.	No Units				NA	
17	*FN*	Fertilizer nitrate.	kg/ha				NA	
17	*FNH*	Fertilizer ammonia.	kg/ha				NA	
17	*FP*	Fertilizer phosphorus.	kg/ha				NA	
17	*DEPIN*	Depth of incorporation.	cm				NA	
17	*FRTWAT*	Depth of water applied for fertigation.	cm				NA	
18	*RATE*	Application rate for animal waste.	tn/ha				NA	
18	*DEPIN*	Depth of incorporation.	cm				NA	
18	*ATN*	Total nitrogen in animal waste.	%				NA	
18	*APORGN*	Organic nitrogen content in animal waste.	%				NA	
18	*ANH*	Ammonia content in animal waste.	%				NA	
18	*APHOS*	Total phosphorus content in animal waste.	%				NA	
18	*APORGP*	Organic phosphorus content in animal waste.	%				NA	
18	*AOM*	Organic matter content in animal waste.	%				NA	
18	*WASTYP*	Type of animal waste (e.g., solid, slurry, or liquid).	No Units				NA	
19	*NTDAY*	Date of tillage, year of crop rotation cycle and Julian day.	No Units				NA	
19	*LTIL*	Code to designate the tillage implement or equipment used.	No Units				NA	
19	*DTIL*	Depth of tillage.	cm				NA	
19	*EFFINC*	Efficiency of incorporation of surface residue.	No Units				NA	
19	*FMIX*	Tillage mixing efficiency.	No Units				NA	

Abbreviations:

AS Application specific parameter value applied to set simulation time periods, output preferences, and parameter codes for particular method applications (e.g., method of fertilization).
DF GLEAMS default parameter value applied.
CAL Calibrated parameter value applied.
GN Generic or example value from p. 191 of the GLEAMS user manual applied unless noted otherwise.
NA Not applicable. Parameter input value may not be required if certain model attributes are not selected. For example, parameter inputs required for fertilizer application would not be required if a particular land use or field is not fertilized.
SS Site-specific parameter value applied.